

**THE INFLUENCE OF FUNCTIONALIZED SBA-15 ON  
THE PRODUCTION OF CITRONELLOL ESTER VIA  
IMMOBILIZED *CANDIDA RUGOSA* LIPASE**

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OF CITRONELLOL ESTER VIA IMMOBILIZED *CANDIDA RUGOSA*  
LIPASE**

**by**

**YASMIN BINTI CHE ANI**

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requirements for the degree  
of Doctor of Philosophy**

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## LIST OF ABBREVIATIONS

<b>2D</b>	2-dimensional
<b>APTES</b>	3-aminopropyltriethoxysilane
<b>APTMS</b>	3-aminopropyltrimethoxysilane
<b>BCA</b>	Bicinchoninic Acid
<b>BET</b>	Brunauer, Emmet and Teller
<b>BJH</b>	Barrett-Joyner-Halenda
<b>BSA</b>	Bovine serum albumin
<b>CALB</b>	<i>Candida antartica</i> lipase B
<b>CRL</b>	<i>Candida rugosa</i> lipase
<b>EA</b>	Elemental Analysis
<b>EDX</b>	Energy Dispersive X-ray
<b>FID</b>	Flame Ionization Detector
<b>FSM</b>	Folded Sheet Material
<b>FT-IR</b>	Fourier Transform Infrared
<b>GC</b>	Gas Chromatography
<b>HCl</b>	Hydrochloric acid
<b>hrs</b>	Hours
<b>i.e.</b>	id est which means that is
<b>K</b>	Kelvin
<b>KBr</b>	Potassium bromide
<b>KH<sub>2</sub>PO<sub>4</sub></b>	Potassium dihydrogen phosphate
<b>KSW</b>	Kanemite Sheets performed at Waseda University
<b>LYS</b>	Lysozyme

<b>MCF</b>	Mesostructured cellular foam
<b>mM</b>	mili Molar
<b>MOMD</b>	manganese-oxides-modified diatomite
<b>MPTMS</b>	3-mercaptopropyltrimethoxysilane
<b>MSU</b>	Michigan state University
<b>MW</b>	Molecular weight
<b>MWCNTs</b>	multi-walled carbon nano-tubes
<b>Na<sub>2</sub>CO<sub>3</sub></b>	Sodium carbonate
<b>NaHCO<sub>3</sub></b>	Sodium bicarbonate
<b>Na<sub>2</sub>HPO<sub>4</sub>.2H<sub>2</sub>O</b>	Disodium hydrogen phosphate
<b>NaOH</b>	Sodium hydroxide
<b>nm</b>	nanometer
<b>P123</b>	Pluronic P123
<b>PEO</b>	polyethylene oxide
<b>PGA</b>	penicillin G acylase
<b>PPL</b>	porcine pancreas lipase
<b>PPO</b>	polypropylene oxide
<b>PXRD</b>	Powder X-Ray Diffraction
<b>rpm</b>	rotations per minute
<b>RSMS</b>	Rod shape mesoporous silica
<b>SBA</b>	Santa Barbara Amorphous
<b>SEM</b>	Scanning Electron Microscopy
<b>SiO<sub>2</sub></b>	Silica dioxide
<b>TCP</b>	Tri block Co Polymer
<b>TEM</b>	Transmission Electron Microscopy

<b>TEOS</b>	Tetraethylorthosilicate
<b>TGA</b>	Thermogravimetric Analysis
<b>UV</b>	Ultraviolet
<b>vs</b>	versus
<b>wt</b>	weight
<b>XRD</b>	X-ray Diffraction

## LIST OF SYMBOLS

$a_L$	Langmuir isotherm constant
$[A]$	Concentration of substrate A
$[B]$	Concentration of substrate B
$B_T$	Temkin isotherm constant related to the heat of adsorption
$b_T$	Temkin isotherm constant
$C_o$	The highest initial concentration of <i>Candida rugosa</i> lipase
$C_e$	The equilibrium concentration of <i>Candida rugosa</i> lipase
$C_i$	The initial concentration of <i>Candida rugosa</i> lipase
$C_t$	The concentration of <i>Candida rugosa</i> lipase at time, $t$
$E_a$	Activation energy
$K_f$	Freundlich isotherm constant
$K_A$	Michaelis-Menten constant for citronellol
$K_B$	Michaelis-Menten constant for octanoic acid
$K_i$	Inhibition constant for octanoic acid
$K_L$	Langmuir isotherm constant
$K_M$	Michaelis constant
$K_M^A$	Michaelis constant for substrate A
$K_M^B$	Michaelis constant for substrate B
$K_S^A$	Dissociation constant for substrate A
$K_T$	Equilibrium binding constant corresponding to the maximum binding energy ( $\Delta G_{\max}$ )
$k_1$	Equilibrium rate constant of pseudo-first sorption
$k_2$	Equilibrium rate constant of pseudo-second sorption
$n$	Adsorption tendency

$q_e$	The amount of <i>Candida rugosa</i> lipase adsorbed at equilibrium
$q_t$	The amount of <i>Candida rugosa</i> lipase adsorbed at time, $t$
$R$	Universal Gas constant
$R_L$	Dimensionless constant separation factor
$R^2$	Correlation coefficient
$T$	Absolute temperature
$t$	Time
$v_o$	Initial velocity
$V$	The volume of the phosphate buffer pH 8.0 solution
$V_{max}$	Maximum velocity
$W$	The weight of mesoporous silica support
$\Delta G$	Gibbs free energy
$\Delta H$	Enthalpy
$\Delta S$	Entropy
$\Delta q$	Normalized standard deviation
$\lambda$	Wavelength

**PENGARUH SBA-15 BERFUNGSI DALAM PENGHASILAN  
SITRONELLOL ESTER MELALUI LIPASE *CANDIDA RUGOSA*  
TERSEKATGERAK**

**ABSTRAK**

Pengesteran enzim menggunakan lipase terbukti mempunyai potensi dalam penghasilan ester. Ini adalah kerana berkurangnya sumber asli yang digunakan dalam penghasilan ester. Sebagai alternatif, sintetik ester yang mempunyai ciri-ciri yang sama dengan bahan alam semulajadi telah dihasilkan. Dalam kajian ini, sitronellil oktanoat ester dikaji sebagai reaksi model.

Lipase tersekatgerak sangat penting dalam proses pengesteran kerana ia boleh diguna semula, proses operasi yang lebih fleksibel dan pemerolehan semula produk dari lipase yang lebih mudah. Oleh itu, SBA-15 berliang meso tulen telah digunakan sebagai sokongan untuk enzim tersekatgerak kerana saiz liang yang lebih besar dan kestabilan haba yang lebih baik. Manakala kaedah bukan hidroterma yang akan menghasilkan ciri-ciri SBA-15 yang sama dengan kaedah hidroterma telah dihasilkan dalam kajian ini. Keadaan terbaik untuk sintesis SBA-15 adalah pada suhu 40 °C, 2.5 M HCl dan 1.79:1 nisbah molar TEOS/TCP yang menghasilkan luas permukaan BET tertinggi iaitu masing-masing 644.14 m<sup>2</sup>/g, 661.17 m<sup>2</sup>/g dan 641.35 m<sup>2</sup>/g. SBA-15 tulen juga berfungsi dengan kumpulan fungsi amina secara sintesis berasingan dalam keadaan refluks pada suhu 85 °C selama 2 jam. Keadaan yang terbaik untuk menyekatgerak SBA-15 tulen dan APTES-SBA-15 dengan *Candida rugosa* lipase (CRL) adalah pada aktiviti enzim 19530 U/mg, pH bufer 8.0 dan pada suhu 35 °C yang memberikan peratusan jumlah enzim terjerap yang tinggi iaitu kira-kira 95 % .